curent

briefly

[called by: mp00ac, dforce.] [calls: coords.]

contents

1.1 enclosed currents

1. In the vacuum region, the enclosed currents are given by either surface integrals of the current density or line integrals of the magnetic field,

$$\int_{\mathcal{S}} \mathbf{j} \cdot d\mathbf{s} = \int_{\partial \mathcal{S}} \mathbf{B} \cdot d\mathbf{l}, \tag{1}$$

   and line integrals are usually easier to compute than surface integrals.

2. The magnetic field is given by the curl of the magnetic vector potential, as described in bfield.

3. The toroidal plasma current is obtained by taking a “poloidal” loop, $d\mathbf{l} = \mathbf{e}_\theta \, d\theta$, on the plasma boundary, where $B^s = 0$, to obtain

$$I \equiv \int_0^{2\pi} \mathbf{B} \cdot \mathbf{e}_\theta \, d\theta = \int_0^{2\pi} \left(-\partial_s A_\zeta \; \bar{g}_{\theta\theta} + \partial_s A_\theta \; \bar{g}_{\theta\zeta} \right) \, d\theta, \tag{2}$$

   where $\bar{g}_{\mu\nu} \equiv g_{\mu\nu} / \sqrt{g}$. This should be independent of ζ.

4. The poloidal “linking” current through the torus is obtained by taking a “toroidal” loop, $d\mathbf{l} = \mathbf{e}_\zeta \, d\zeta$, on the plasma boundary to obtain

$$G \equiv \int_0^{2\pi} \mathbf{B} \cdot \mathbf{e}_\zeta \, d\zeta = \int_0^{2\pi} \left(-\partial_s A_\zeta \; \bar{g}_{\theta\zeta} + \partial_s A_\theta \; \bar{g}_{\zeta\zeta} \right) \, d\zeta. \tag{3}$$

   This should be independent of θ.

1.2 “Fourier integration”

1. Using $f \equiv -\partial_s A_\zeta \; \bar{g}_{\theta\theta} + \partial_s A_\theta \; \bar{g}_{\theta\zeta}$, the integral for the plasma current is

$$I = \sum_i{}' f_i \cos(n_i \zeta) 2\pi, \tag{4}$$

   where $\sum'$ includes only the $m_i = 0$ harmonics.

2. Using $g \equiv -\partial_s A_\zeta \; \bar{g}_{\theta\zeta} + \partial_s A_\theta \; \bar{g}_{\zeta\zeta}$, the integral for the linking current is

$$G = \sum_i{}' g_i \cos(m_i \zeta) 2\pi, \tag{5}$$

   where $\sum'$ includes only the $n_i = 0$ harmonics.

1.3 Comments

1. The plasma current, Eqn.(2) & Eqn.(4), should be independent of ζ, and the linking current, Eqn.(3) & Eqn.(5), should be independent of θ. (Perhaps this can be proved analytically; in any case it should be confirmed numerically.)

2. This routine also calculates the derivatives of the enclosed currents w.r.t. the geometry and the fluxes. This requires the appropriate derivatives of the vector potential, and for this please learn about the `ideriv` parameter and what information is contained in the `Ate(lvol,ideriv,ii)%s(ll)`, and `Aze(lvol,ideriv,ii)%s(ll)` arrays.